Can there be a Science of Simulation? Why should we care?

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To any traditional scientist, the thought of a "science" of simulation at best appears misinformed and at worst grates on the scientific sensibility worse than fingernails dragging across a chalkboard. I think that we all agree that no such science currently exists.

The hypothesis I want to test is whether a science of simulation could exist.

I began by looking at scientific definitions of science to identify its salient characteristics. These definitions show an amazing consistency considering the past liberal applications of the term science to various nonscientific activities. They suggest that a science has a few essential properties:

1. Science is a study.
2. It deals with the natural or physical world.
3. That study takes place through experimentation and development of theoretical explanation.
4. Its theoretical explanation (stated in terms of hypotheses, models, laws and principles) arises from and is confirmed by observation and experiment.

I tested the nature of simulation against each of these properties. Here are my findings in this experiment.

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1. *Can simulation by studied?* One could certainly study, in the broadest sense, simulation. Many stately bodies of higher education offer courses and even entire curricula purporting to teach simulation. These observations lead me to conclude that the study of simulation could exist in some form. That conclusion meets the first criterion of being a science.

2. *Is simulation a part of the physical or natural world?* Certainly many simulations deal explicitly with the physical or natural world but are simulations actually part of the physical or natural world themselves? Simulations are constructed by people and are not part of the natural world. But wait, the Academic Press Dictionary of Science and Technology defines the physical world as synonymous with the material world which contains physical objects rather than emotions or the spiritual world. Simulations, the objects in the simulation world, do not generally contain emotions nor do they represent the spiritual world (at least as far as I know). Further, the development of simulations does not necessarily need reference to emotional or spiritual objects (although I'm sure that some program managers would argue this). Therefore, simulations must be part of the physical world and so do meet the second criterion to be subject to scientific study.

3. *Can simulation be subject to experimentation and can these lead to theoretical explanations?* Experimentation, involves a procedure carried out under controlled conditions in order to discover, demonstrate, or test some fact, theory or general truth. This definition implies that a system subject to experimentation must

- Exhibit observable behavior, and
- Respond to controls of its behavior.

Thus, experiments cannot really be performed upon systems that either are not observable or are not controllable.

Most of the artifacts of simulations (e.g., designs, software, computers, results) are observable. I do not believe that we could construct simulations without many artifacts that would facilitate observation. This suggests that both simulations and their development are observable.

People are inextricably involved in simulation development and often in their execution. Where people are not involved, computers perform most operations. Both of these elements are controllable. The field of psychology has repeatedly demonstrated controlled experiments involving people and computer science has repeatedly demonstrated controlled experiments involving computers. The success of these demonstrations shows that controlled experiments could be formulated and executed upon simulations to examine their behavior and the behavior of the processes involved in their creation. Admittedly, simulation project managers might argue against the controllability of the simulation development process but we, like most others, will ignore those pleas. Therefore, study of simulations could realistically involve experimentation. Some would even argue that some of those experiments have already been performed. The ability to develop theoretical explanations of the experimental results clearly exists since many people have proposed theoretical explanations of various aspects of simulation without the benefit of experiments. Therefore, simulation satisfies the third criterion to be subject to science.

4. *Can explanations be confirmed by experiment?* The final criterion remains untested in simulation and presents the major challenge in realizing the science of simulation. No clear physical barriers appear to exist to prevent the systematic study of simulation suggested by this criterion. However, only trying to execute this study can prove or disprove this criterion—we won't know till we try.

So, the jury remains out on this criterion. Actually, the court has not yet been called into session. The final answer to whether a science of simulation could exist awaits someone brave enough to begin performing a systematic study of simulations and the processes for realizing them. No doubt, many physical and cultural hazards face any such individual, perhaps, these will deter many. Hopefully, human curiosity will prevail and someone will gallantly ignore the naysayers and try.

What value does knowledge derived from scientific study possess over knowledge derived from any other form of study? To me (unarguably a science zealot), science reaches for the surest truth, truth that applies broadly and persists over time. Science creates the most powerful form of knowledge. The assurance that real science provides the foundation of much of the engineering practice that has created the world we know today. Scientific study has even permeated the justice system to some extent (e.g., genetic evidence) and I am confident that it will continue to do so. Over the few thousand years of its development, science has evolved into a very robust and consistent source of knowledge unsurpassed by all other sources. This type of knowledge about simulation would surely provide tangible benefits beyond our meager imaginations as it has in many other fields. Another important benefit is that science provides the knowledge that we could confidently teach to improve the capabilities of the practitioners in the field.

The origins of this article lie in an e-mail discussion among Dell Lunceford, Bill Waite, Richard Fujimoto, Ernie Page and Scott Harmon. Readers are invited to offer their perspectives for publication in future issues.